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102. Changes in Distribution of Trout in Great Smoky Mountains National Park, 1900-1977

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102. Changes in Distribution of Trout in Great Smoky Mountains National Park, 1900-1977

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Changes in Distribution of Trout in Great Smoky Mountains National Park, 1900-1977

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Abstract

Significant changes have occurred in the distribution of trout in streams of Great Smoky Mountains National Park since 1900. By the mid-1970's the original range of the native brook trout (*Salvelinus fontinalis*) had been reduced by about 70% and the species was relegated to sub-optimal habitat in headwater streams. Most of the stream sections lost by brook trout became the territory of the introduced rainbow trout (*Salmo gairdneri*), which in 1977 occupied about 80% of the Park waters. After 1950, brown trout (*Salmo trutta*) introduced in State waters outside the Park established reproducing populations in some 50 miles of stream formerly occupied only by rainbow trout. If current trends continue, the recovery of brook trout in Park water may be difficult, if not impossible, and brown trout may occupy much of the territory now held by rainbow trout.

The Great Smoky Mountains reach their greatest elevations in the Southern Appalachian Highlands of eastern Tennessee and western North Carolina. Great Smoky Mountains National Park (GSMNP) lies in the heart of this region. The Park boundary includes a rugged mountain mass extending in a general east-west direction, following the Tennessee-North Carolina State line for nearly 60 miles, and varying in width from 10 to 30 miles. It ranges in elevation from 850 feet above mean sea level (msl) at the mouth of Abrams Creek to 6642 feet at the top of Clingman's Dome. The Park boundaries now protect an 800-square-mile area of mountain wilderness, which includes many unspoiled watersheds that provide fishing for wild trout. There are over 700 miles of trout streams in the Park, inhabited by some 70 species of fish. The brook trout (*Salvelinus fontinalis*) is the only salmonid native to the region.

The distribution of trout occupying the streams of GSMNP changed considerably between 1900 and 1977. In 1900 the brook trout was the dominant salmonid in the area that later (1926) was established as GSMNP. Extensive logging from 1903 to 1935, however, drastically reduced the brook trout population in Park waters (King 1937). By 1942 the rainbow trout (*Salmo gairdneri*), introduced in the lower sections of almost every major Park stream from 1910 to 1930, had moved into much of the area lost by the brook trout and was also invading waters still containing established brook trout populations.

Another change was occurring in the lower sections of Park streams. By 1950 brown trout (*Salmo trutta*) that had been introduced into adjacent State waters had invaded rainbow trout waters of the Park, and by 1977 they occupied over 50 miles of the Park streams formerly held by rainbow trout.

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The purpose of the present paper is twofold. First, we summarize the changes that have occurred in the trout populations of GSMNP since 1900, as described by King (1937) for the 1930's and Lennon (1967) for the 1950's, and the reasons these authors thought were responsible for the changes. Second, and most important, we present the results of our 1972-77 fishery survey of waters in GSMNP and discuss the changes in trout distribution that this survey revealed, along with possible causes and consequences of these changes.

Trout Distribution

Before 1900

King (1937), who described stream conditions that existed before extensive logging occurred in the GSMNP area in the early 1900's, reported that brook trout thrived in Park streams, generally more than 2000 feet above msl. The lowest point of their range was at 1600 feet in the Middle Prong Little Pigeon River, and at 2000 feet in the Oconaluftee River and Bradley Fork watersheds. He stated that no game fish occupied the sections of streams 1 to 5 miles below the lower range of the brook trout, and that smallmouth bass (*Micropterus dolomieui*) were found below an average elevation of 1600 feet.

1903 to 1959

King (1937) described the events that occurred between 1903 and 1930 that led to an estimated 55% decline in the brook trout range. He stated that by 1935 the reproducing population of brook trout had moved from an average elevation of 2000 feet in 1903 to above 3000 feet, losing more than 160 miles of stream in that 30-year period. Many miles of brook trout water were lost in such watersheds as those of the East Prong of the Little River, Middle Prong of the Little Pigeon River, Oconaluftee River, and others throughout the Park.

In the mid-1950's, when Lennon conducted the first survey of major Park streams since King's surveys of the 1930's, he found that there had been no significant downstream extension of brook trout range since 1935, but rather that the range had further declined by about 15%.

1959 to 1977

The next two decades brought even further changes in trout distribution within GSMNP, as indicated by our survey of Park waters in 1972-77. The objective of the survey was to determine the distribution of trout within GSMNP and to compare it with the distributions described by King (1937) and Lennon (1967). We conducted surveys on all major streams and tributaries, using electrofishing apparatus, at various intervals from the mouths to the uppermost headwaters. Waterfalls and cascades seen in the streams were recorded as possible physical barriers to fish movement. During the surveys, 528-foot sections were sampled at several points along each stream, and the lengths and weights of all fish collected were recorded, along with water temperature and pH.

We found that the brook trout population had further declined and the rainbow trout population had correspondingly increased (Table 1). Brook trout occupied about 123 miles of stream in GSMNP, but only 40 miles were above functional physical barriers that would prevent the entry of rainbow trout. The average minimum stream elevation for brook trout in 1972-77 was about 1500 feet higher than in 1900. Waterfalls seemed to be a major factor in limiting the upstream movement of rainbow trout. In the few streams that had effective physical barriers, the distribution of brook trout had changed little since the 1940's. However, in most streams without such barriers (e.g., the headwater streams of the East Prong and Middle Prong of Little River), the brook trout not only failed to reclaim territory lost before the 1930's (Lennon 1967), but lost additional range to rainbow trout. In watersheds that were heavily stocked with rainbow trout over the past 50 years, such as the East Prong of Little River, the increase in the range of rainbow trout was much more extensive than in watersheds such as Raven Fork, which were less heavily stocked. Our survey also revealed that brown trout had made extensive invasions into existing rainbow trout waters (Table 1), and had established reproducing populations in more than 50 miles of Park streams.

Causes of Changes in Trout Distribution

King (1937) listed several major causes of brook trout decline: (1) logging, with its resulting sedimentation and loss of stream shading, and accompanying damming, fires, and railroad building; (2) fishing with bait, nets, and dynamite; and (3) introduction of the exotic rainbow trout in practically every major stream in GSMNP. Early records at GSMNP and accounts by "old-timers" indicate that rainbow trout were commonly stocked in headwater streams above waterfalls that might otherwise have prevented their upstream movement. He listed reasons why rainbow trout were able to survive under stream conditions as

Table 1. *Maximum and minimum elevations (feet above mean sea level) at which different species of trout were collected in streams of the Great Smoky Mountains National Park in 1972-77.* [Abbreviations: Dashes = species not found; H = uppermost headwaters; M = mouth; PB = park boundary; WF = waterfalls]

Watershed, year sampled, and stream	Maximum elevation at which species of trout were found		Minimum elevation at which species of trout were found	
	Brown and rainbow	Rainbow only	Rainbow and brook	Brook only
Abrams Creek (1973)				
Mainstream	[a]	H	—	—
Panther Creek	—	H	—	—
Parson Branch[b]	—	H	—	—
Rabbit Creek[b]	—	H	—	—
Mill Creek				
Mainstream	—	2600	—	—
Sugar Cove Creek	—	H	—	—
Narrow Creek	—	H	—	—
Forge Creek[b]	—	H	—	—
Abrams Creek (within Cades Cove)[b]	[a]	H	—	—
Anthony Creek				
Mainstream	—	2800	—	—
Left Prong Creek	—	H	—	—
Little River (1974)				
West Prong Little River[b]	—	H	—	—
Middle Prong Little River (1974)				
Mainstream	1500	H	—	—
Thunderhead Prong				
Mainstream	—	3600	—	—
Sams Creek				
Mainstream	—	2790	2800	3200
Starkey Creek	—	3160	M	3200
Lynn Camp Prong				
Mainstream	—	3190	3200	3700
Marks Creek	—	2430	2440	2920
Indian Flats Prong	—	2910	2920[c]	3000, WF
East Prong Little River (1975)				
Mainstream	2200	4150	4160	4360
Meigs Creek	—	1650	1660[d]	1700
Jakes Creek	—	H	—	—
Huskey Branch	—	—	—	M, WF
Fish Camp Prong				
Mainstream	—	3390	3400	4000
Goshen Prong	—	3510	3520	3680, WF
Silers Creek	—	3390	3400	3800
Narrows Branch	—	—	—	M
Buckeye Gap Prong	—	—	M	4000
Meigs Post Prong				
Mainstream	—	3650	3660	3700, WF
Sweet Creek	—	—	—	M
Kuwahi Branch	—	—	M	4000
Grouse Creek				
Mainstream	—	—	M	3720
Spud Town Branch	—	—	—	M
Rattler Branch	—	—	—	M

Table 1. Continued.

Watershed, year sampled, and stream	Maximum elevation at which species of trout were found		Minimum elevation at which species of trout were found	
	Brown and rainbow	Rainbow only	Rainbow and brook	Brook only
Little Pigeon River (1975)				
West Prong Little Pigeon River				
Mainstream	1760	4600	–	–
Road Prong	–	3470	3480	3680
Walker Camp Prong				
Mainstream	–	4400	–	4680
Alum Cave Creek	–	–	M	3920
LeConte Creek	–	2800	–	–
Roaring Fork Creek	–	3400	–	–
Dudley Creek				
Mainstream	–	1790	1800[c]	–
Little Dudley Creek	–	H	–	–
Twin Creek	–	–	M	–
Middle Prong Little Pigeon River				
Mainstream	–	2390	2400	3200
Injun Creek	–	H	–	–
Rhododendron Creek[b]	–	H	–	–
Porters Creek				
Mainstream	–	3000	–	–
False Gap Prong	–	H	–	–
Long Branch	–	H	–	–
Cannon Creek[b]	–	H	–	–
Lowes Creek	–	2520	–	–
Boulevard Prong	–	3200	–	–
Shutts Prong	–	3200	–	–
Lester Prong	–	–	–	–
Ramsey Prong	–	–	M	–
Buck Fork	–	–	M	3800
Eagle Rocks Prong	–	–	M	3040
Chapman Prong	–	–	–	M
Lost Prong	–	–	–	M
East Prong Little Pigeon River				
Dunn Creek	–	–	–	PB
Indian Camp Creek	–	2150	2160	2200
Cosby Creek (1975)				
Mainstream	–	2470	2480	2800
Crying Creek[b]	–	H	–	–
Toms Creek	–	–	M	2040
Rock Creek	–	–	M	2080
Camel Hump Creek	–	–	M	2800
Dry Branch	–	–	M	2800
Big Creek (1976)				
Mainstream	–	3390	3400	4320
Mouse Creek	–	3000	–	–
Swallow Fork	–	3430	3440	4160
McGinty Creek	–	3630	3640	4050
Gunter Fork	–	3190	3200	3800
Sinking Creek	–	–	M	3880
Yellow Creek	–	–	M	–
Deer Creek	–	–	M	4520

Table 1. Continued.

Watershed, year sampled, and stream	Maximum elevation at which species of trout were found		Minimum elevation at which species of trout were found	
	Brown and rainbow	Rainbow only	Rainbow and brook	Brook only
Cataloochee Creek (1972)				
Mainstream	2000	H	–	–
Little Cataloochee Creek				
Mainstream	–	–	2720	–
Correll Branch[b]	–	–	–	M
Coggins Branch	–	H	–	–
Conrad Branch	–	H	–	–
Woody Branch	–	–	M	–
Andy Branch	–	H	–	–
Caldwell Fork				
Mainstream	–	H	–	–
McKee Branch	–	H	–	–
Palmer Creek				
Mainstream	–	2290	3000	–
Rough Fork				
Mainstream	–	3590	3600	–
Woody Creek	–	–	M	3800
George Ira Creek	–	–	M	3800
Horse Creek	–	–	M	3920
Bear Creek	–	–	M	3920
Davidson Branch[b]	–	H	–	–
Pretty Hollow Creek				
Mainstream	–	3170	3180	4000
Cooks Creek	–	–	M	4600
Lost Bottom Creek	–	–	M	3600, WF
Falling Rock Creek	–	–	M	3960
Beech Creek	–	–	M	4000
Oconaluftee River (1973)				
Mainstream	2400	H	–	–
Raven Fork				
Mainstream	2000	3540	3550	–
Straight Fork				
Mainstream	–	3270	3280	4000
Bunches Creek				
Mainstream	–	–	PB	4000
Flat Creek	–	–	–	M
Heintooga Creek	–	–	PB	3600
Right Fork Redman Creek	–	–	PB	4000
Left Fork Redman Creek	–	–	PB	3800
Stillwell Creek	–	–	–	PB
Hyatt Creek	–	3000	3000	3800
Round Bottom Creek	–	3030	3040	3080
Ledge Creek	–	3070	3080	3700
Right Prong	–	–	M	–
Balsam Corner Creek	–	–	–	M
Enloe Creek	–	–	M	3800, WF
Bulldie Creek[b]	–	–	M	–
Right Fork Raven Fork River	–	–	M	4280
Middle Fork Raven Fork River	–	–	M	4240
Left Fork Raven Fork River	–	–	M	4280
Mingus Creek[b]	–	H	–	–

Table 1. Continued.

Watershed, year sampled, and stream	Maximum elevation at which species of trout were found		Minimum elevation at which species of trout were found	
	Brown and rainbow	Rainbow only	Rainbow and brook	Brook only
Couches Creek	–	2500	–	–
Bradley Fork				
Mainstream	2350	–	3160	–
Chasteen Creek	–	2990	3000	–
Taywa Creek	–	3310	3320	3640
Tennessee Branch	–	–	M	3080
Louie Camp Branch	–	–	M	3320
Bear Wallow Branch	–	–	M	3640
Chasm Prong	–	–	M	2480
Gulf Prong	–	–	M	3560
Collins Creek	–	2470	2480	3400
Kephart Prong	–	3600	3800	–
Kanati Fork	–	–	–	M
Aden Branch	–	–	–	M
Peruvian Creek	–	–	–	–
Minnie Ball Branch	–	–	–	M
Deep Creek (1974)				
Mainstream	3600	3590	3600	–
Bridge Creek	–	H	–	–
Pole Road Creek	2560	2790	2800	3400
Left Fork Deep Creek				
Mainstream	3470	–	3480	4200
Bearpen Branch	–	H	–	–
Hermit Branch	–	H	–	–
Keg Drive Branch	–	–	M	3800
Nettle Creek	2800	H	–	–
Beetree Creek	2880	–	2890	3400
Cherry Creek	2920	H	–	–
Rocky Fork	–	–	M	4200
Sahlee Creek	–	–	M	–
Noland Creek (1975)				
Mainstream	2000	3190	3200	4160
Bearpen Branch	–	H	–	–
Mill Creek				
Mainstream	–	3390	3400	–
Springhouse Branch	–	H	–	–
Bald Branch	–	–	M	4120
Salola Branch	–	–	M	4160
Clingmans Creek	–	–	–	M
Forney Creek (1975)				
Mainstream	–	3790	3800	–
Bear Creek	–	H	–	–
Advalorem Branch	–	H	–	–
Bee Gum Branch	–	H	–	–
Slab Camp Branch	–	H	–	–
Whitemans Glory Creek	–	2580	–	–
Jonas Creek[b]	–	H	–	–
Huggins Creek				
Mainstream	–	3190	3200	3680
Little Huggins Creek	–	–	–	M
Steeltrap Creek	–	H	–	–
Keeyuga Creek	–	–	–	M

Table 1. Continued.

Watershed, year sampled, and stream	Maximum elevation at which species of trout were found		Minimum elevation at which species of trout were found	
	Brown and rainbow	Rainbow only	Rainbow and brook	Brook only
Hazel Creek (1976)				
Mainstream	—	3030	3040	3750
Haw Gap Branch	—	H	—	—
Bone Valley				
Mainstream	—	2710	2710	—
Wooly Ridge Branch	—	H	—	—
Defeat Branch	—	—	M	2800, WF
Desolation Branch[b]	—	—	M	—
Roaring Creek	—	—	M	—
Walker Creek	—	3240	3250	3680, WF
Brushy Branch	—	—	M	—
Proctor Creek[b]	—	—	M	—
Eagle Creek (1977)				
Mainstream	—	H	—	—
Lost Cove Creek[b]	—	H	—	—
Ekaneetlee Creek	—	2750	2760	—
Tub Mill Creek	—	2990	3000	—
Lawson Gant Lot Branch	—	H	—	—
Asgini Branch	—	—	M	—
Gunna Creek	—	2840	2850	3160
Paw Paw Creek	—	3200	—	—
Twenty Mile (1977)				
Mainstream[b]	1500	H	—	—
Moore Springs Branch				
Mainstream	—	2600	—	—
Dalton Branch	—	1850	—	—

[a]Creel reports indicate brown trout present.
[b]Includes all tributaries.
[c]Brook trout stocked 1969.
[d]Brook trout stocked 1969 and 1975.

they existed between 1903 and 1935, and why they were able to compete with brook trout after this period, stating that rainbow trout were able to withstand higher temperatures and higher amounts of silt and pollution than brook trout, reached a larger size, and were more difficult to catch by anglers.

Several factors that seemed to limit the upstream movement of rainbow trout in the 1930's still appeared to be the major controlling factors in 1972-77: the presence of a falls 8 feet high or higher, the preference of rainbow trout for large streams rather than small tributaries, and the low tolerance of rainbow trout for acid streams. King (1937) wrote that, even in areas of the Park where the effects of logging were not relevant (such as Middle Prong Little Pigeon River, Deep Creek, and Cataloochee Creek), brook trout were eliminated from lower stream reaches by the introduction of rainbow trout, in combination with heavy fishing pressure. He stated that the nature of the competition between rainbow trout and brook trout was not clearly understood but that it appeared to be related to competition for food organisms rather than to antagonism.

All logging operations were completed in GSMNP by 1935, and as streams that had been adversely affected by poor logging practices began to recover, it was assumed that the brook trout would regain much of its lost territory (King 1937). Park managers stocked 200,000 hatchery-reared native brook trout annually for 3 years (1937-39). Heavy stocking of brook trout continued from 1940 to 1947, but the fish planted were from a New England strain, which A. D. Holloway (unpublished manuscript) apparently considered to be less hardy than the native Appalachian strain; he recommended that only the Appalachian strain be used in the future. In 1948 stocking of all brook trout was sharply curtailed.

Lennon (1967), who addressed the question of why the brook trout did not recover the territory they lost before 1935, listed several major possible reasons: small size, short life span, unbalanced sex ratio of mature fish, an unidentified ovarian disease, low fecundity, low numbers of redds and young of the year, and high susceptibility to furunculosis and ulcer disease. Although he analyzed water quality of Park streams, he was unable to detect any changes in the habitat of the brook trout that would depress survival or the availability of food organisms. After our 1972-77 survey, we examined changes in water conditions over the previous two decades to determine if any factors could be singled out as major causes for the brook trout's failure to recover lost territory.

Water temperature, which is generally considered to be the most important factor affecting the geographical distribution of brook trout (MacCrimmon and Campbell 1969), was among the factors considered. Although data are sparse, summer temperatures in stream areas recently vacated by brook trout rarely appeared to exceed the 16°C value normally considered best suited for their well-being, as outlined by MacCrimmon and Campbell. However, Morgan et al. (1976) observed August temperatures of 17.5°C for a short period in one section of Cosby Creek. Winter temperatures (discussed later) probably play a greater role in brook trout survival.

Among other environmental factors that could affect trout populations are severe floods, which scour stream beds; sedimentation; fire, which reduces stream shading (King 1937); toxicity from heavy metals or biocides; and long-term changes in pH. Floods occur regularly in the Appalachians, and undoubtedly play a major role in survival of young-of-the-year trout there, as they do elsewhere (Elwood and Waters 1969; Hoopes 1975). F. R. Richardson (personal communication) gathered data in the 1960's which indicated that flooding had a greater negative effect on brook trout than on rainbow trout. However, we know of no evidence indicating that the frequency of flooding is greater now than it was decades ago. Also, to the best of our knowledge, neither fire nor the direct or indirect effects of toxicity play a major role in the ecology of Great Smoky Mountains trout.

Changes in pH are known to occur in GSMNP waters as a result of man's activities (Huckabee et al. 1975) and may also result from broad-scale acid precipitation (Cogbill and Likens 1975). Such changes could significantly affect survival of stream fishes and should be studied further. On a comparative basis, however, studies with fingerling brook trout (Daye and Garside 1975) and rainbow trout (Kwain 1975) indicated that the brook trout are the more tolerant of acid conditions. Naturally acidic conditions do affect distribution of brook trout within the Park (Huckabee et al. 1975), and recent research (especially by Menendez 1976) suggested that "moderate" acidity (pH 6.0–6.5) may significantly reduce survival of young life stages of brook trout. We found, however, that pH values in average Park streams range from 6.7 to 6.9, and in the light of recent evidence that acid tolerance is hereditary (Robinson et al. 1976) and likely to be inbred in native populations, we doubt that low pH is a major factor in the decline of Park brook trout. Low pH may, however, limit the spawning and upstream movement of rainbow trout into brook trout streams.

Interaction of Brook Trout with Other Species

The analysis of species interactions is complex, and is especially difficult in GSMNP because of the lack of basic life history data and behavioral observations. For nearly 40 years, other fish species (particularly rainbow trout) have been labeled as the major culprit causing (in unspecified ways) the reduction of the brook trout in the Park. The only nonsalmonid whose range overlaps with brook trout in the Park is the blacknosed dace (*Rhinichthys atratulus*). Although Harned (1976) found that the food of these two species overlapped considerably, and hypothesized that the presence of the dace could reduce the stream's carrying capacity for trout, dace probably would not seriously affect the general growth or survival of trout in the Park, because their range overlaps that of brook trout in only a few Park streams.

Rainbow trout may interact with brook trout because both species seek similar resources—especially food, suitable habitat, and spawning sites—which may or may not be in short supply. If these resources are not limiting, their use by both species may not be detrimental to either. It is also possible for both species to gradually modify aspects of their behavior while living sympatrically so that they may come to live in proximity but use essentially different resources (Griffith 1972). However, these changes are difficult to detect without detailed observations over a long period of time. Adult brook trout in small streams in other regions of North America occupy territories whose focal points are closely associated with overhead cover (Gibson and Power 1975) and currents of 0.26–0.33 foot per second (Griffith 1972). Our observations in the Park suggest similar patterns. Brook trout are usually found in the side areas of pools or facing downstream in back-eddies close to physical cover, whereas rainbow trout are found in faster water, the largest individuals occupying territories at the heads of larger pools where the water is turbulent. This observation, which is supported by observations in other areas of the country, suggests that, although

headwater streams are satisfactory habitat for brook trout, slower and deeper water with more submerged and overhead cover (not just shading) is preferred.

Defense of territories depends, among other things, on the size, number, and species of fish involved. Brook and rainbow trout communicate effectively by using similar behavioral signs (Newman 1956), and begin to display aggression soon after hatching. The Park brook trout spawn in the fall and the eggs hatch in February or March; the fry reach a length of about ¼ inch by mid-June (Morgan et al. 1976, and personal observation). Though rainbow trout spawn in the spring, length of the young may equal that of the brook trout by July. Thus, for a short period, brook trout have a size advantage over rainbow trout. However, this is soon lost and never regained: the length of young rainbow trout surpasses that of the young brook trout by the end of their first summer. Studies of other salmonids (Chapman and Bjornn 1969) have indicated that behavioral encounters may be crucial during this first growing season because subordinate individuals without territories may be forced to migrate downstream and are lost to the population. Determining whether those behavioral encounters occur in the brook trout in the Park would be informative. After an initial "settling-in" period during their first few months of life, the social structure of single or multiple species groups becomes structured with few behavioral encounters—except for the readjustments required after seasonal movements, as they occur.

Whether food supplies ultimately limit trout populations in the Park is yet to be demonstrated, but food organisms in headwater areas are restricted in diversity and quantity. No evidence exists to support the possibility that rainbow trout gain an advantage in feeding efficiency, because diets of the two species are relatively similar (Tebo and Hassler 1963; Morgan et al. 1976). Morgan et al. (1976) showed that brook trout fed more commonly on crayfish, demonstrating their affinity for benthic prey (Griffith 1974).

We have observed that brook trout in GSMNP lay as few as 100 eggs per redd, and rainbow trout as many as 800, in streams where the ranges of brook and rainbow trout overlap. Environmental factors, particularly ice buildup due to low ground flows in winter (Lennon 1967), are important here and may be augmented by interspecific interaction. We speculate that aggressive rainbow trout may effectively interfere with spawning brook trout. The possibility of an ovarian disease in brook trout mentioned by Lennon (1967) remains unresolved.

Our observations of the two species in GSMNP have revealed significant differences in fecundity, age at initial reproduction of females, the number of spawnings, and longevity—all of which favor the rainbow trout.

Effects of Angling

Information on angling in GSMNP is limited. The differences in angling vulnerability between brook trout and rainbow trout, however, are well documented—the brook trout being the more susceptible. This factor would be most important to the interspecific balance in Park waters if brook trout are preferentially removed from the zones where the two species overlap. Illegal fishing has also been (and continues to be) a factor, especially in the more remote areas normally inhabited by brook trout. In streams where pure brook trout populations have been present for many years, fishing pressure has always been a factor in the brook trout's survival. However, fishing pressure in the remote brook trout areas is limited, and pure brook trout populations that have been isolated from invading rainbow trout by natural waterfall barriers have survived fishing pressure, including poaching, for decades. Only in areas where the species overlap does fishing pressure seem to cause more than a temporary reduction in brook trout, due to the high susceptibility of this species to angling.

Discussion

It is clear that many factors are operating on brook trout populations in the Great Smoky Mountains National Park, and almost all are tipping the balance away from the survival of the species. We view the presence of a competing species (primarily the rainbow trout, although several other species may also be involved) as perhaps the most important threatening factor. Without a competitor, brook trout could probably maintain a moderate population in many streams in which they once lived. However, with rainbow trout present, we believe that the brook trout population may continue to decline for two reasons: (1) rainbow trout may continue to work their way upstream until they reach a physical or chemical barrier, and (2) brook trout and rainbow trout will probably never effectively segregate and allow a substantial recovery of the brook trout population.

The mechanics of interaction between the species is still a matter of conjecture. It is to be hoped that research will provide more of the needed information. How do rainbow trout gain an initial foothold in stream areas occupied by brook trout if, for instance, the available habitat is completely saturated by brook trout? We hypothesize two possible mechanisms: either brook trout (especially young of the year) are temporarily reduced in numbers by factors such as anchor ice, floods, and immigration of young rainbow trout, or adult rainbow trout are moving upstream and, because of their greater size, cannot be displaced by resident brook trout.

Attempts to restock former brook trout streams with hatchery fingerlings during the past 40 years have met with little success. An attempt was made by King (1942) to supplant the rainbow trout and restore brook trout in Indian Creek by stocking a northern strain of brook trout. Nearly 30,000 brook trout 3 to 6 inches long were stocked in 5 miles of stream from 1936 to 1939. However, a survey in 1940 indicated that the species persisted only in the headwaters (King 1942). The failure of brook trout in this instance may have been a result of competition from established rainbow trout or the unsuitability of the northern strain of brook trout used (Lennon 1959). In 1957 Lennon made a second attempt to reclaim Indian Creek for brook trout by attempting to eradicate existing populations of rainbow trout and then restocking an Appalachian strain of brook trout. The mouth of Indian Creek was protected from re-invading rainbow trout by a 30-foot waterfall. The eradication of rainbow trout was judged successful, except for some 35 fry that could have been the survivors of late-hatching eggs at the time of the stream treatments (Lennon 1967). The stream was then stocked with 12,000 native brook trout and an additional 12,000 the following year. Lennon (1959) concluded that there was good reason to believe that the native strain of brook trout would become established in Indian Creek. However, our survey in 1974 revealed no brook trout, but a thriving population of rainbow trout. From 1965 to 1975, attempts were made to reestablish former brook trout populations in several other streams by using hatchery stock of northern strains of brook trout. Although these streams contained no rainbow trout, reproducing populations of brook trout were not established.

If invasion of brook trout range by the rainbow trout continues, along with the brown trout's invasion of rainbow trout territory, not only will the recovery of the brook trout be rendered virtually impossible, but there could be a complete change in the species of fish that dominate the waters of GSMNP in the future.

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